Chapter

FINANCIAL CLOUDS AND MODELLING OFFERED BY CLOUD COMPUTING ADOPTION FRAMEWORK

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ABSTRACT

Cloud Computing Adoption Framework (CCAF) is a framework for designing and implementation of Could Computing solutions. This paper focuses on how CCAF can help to address portability in Cloud Computing implementations in Finance domain. Portability involves migrating entire applications from desktops to clouds and between different Clouds in a way which is transparent to users so they may continue to work as if still using their familiar systems. Reviews for several financial models are studied, where Monte Carlo Methods (MCM) and Black Scholes Model (BSM) are chosen to demonstrate portability between desktops and clouds. A special technique in MCM, Variance-Gamma Process, is used for error corrections while performing analysis of good quality. Coding algorithm for MCM and BSM written in MATLAB are explained. Simulations for MCM and BSM are performed on different types of Clouds. Benchmark and experimental results are presented and discussed, together with implications for banking and ways to track risks in order to improve accuracy. We have used a conceptual Financial Cloud platform to explain how this fits into the CCAF, as well as Financial Software as a Service (FSaaS). Our objective is to demonstrate portability, speed, accuracy and reliability of applications in the clouds, while demonstrating portability for CCAF and FSaaS.

Keywords:

Financial Clouds; Cloud Computing Adoption Framework (CCAF); Monte Carlo Methods; Monte Carlo Simulations; Black Scholes Model; Financial Software as a Service (FSaaS); Variance-Gamma Processes (VPG); MATLAB SaaS applications on Clouds; programming methods for Cloud Computing; enterprise portability for Clouds.

1. INTRODUCTION

Finding solutions to the Global economic downturn triggered by the finance sector is an interdisciplinary research problem which requires that experts from different sectors work altogether. There are different interpretations for the cause of the problem. Firstly, Lord Turner, Chair of the Financial Service Authority (FSA), is quoted as follows: “The problem, he said, was that the banks' mathematical models assumed a ‘normal’ or ‘Gaussian’ distribution of events, represented by the bell curve, which dangerously underestimated the risk of something going seriously wrong.” (Financial Times, June 2009). Secondly, there were reports of a lack of regulations on financial practices. Currently remedies are being proposed by several governments to improve on this (Financial Times, 2010; City A.M, 2010). Thirdly, there was the “Madness of Mortgage Lenders” as identified in a study conducted by Hamnett (2009) whereby uncontrolled lending to those who could not afford to repay led to a housing bubble and subsequent collapse. Irresponsible mortgage lending was a key factor in the collapse of Lehman Brothers which seemed to trigger the global financial crisis. All the above in combination contributed to creating the conditions that led to the global downturn.

All the above suggested possibilities contribute to complexity that caused global downturn. The global economic downturn triggered by finance sector is an interdisciplinary research question that the use of Cloud resources offers innovative approaches for risk analysis, and knowledge sharing in a community-oriented and professional platform (Feiman and Cearley, 2009). Cloud resources can be used to improve accuracy of risk analysis, financial modelling and knowledge sharing in an open and professional platform (Buyya et al. 2009; Chang et al, 2010 a; 2010 c; 2011 b; 2011 c; 2011 d; 2013 a). There are demonstrations presented by authors to confirm the added values of Cloud adoption, and sectors including healthcare, finance and education receive added value including improvement in efficiency, collaboration, revenue, cost-savings and service rating in healthcare, finance and education sectors as a result of Cloud adoption (Chang et al. 2011 d; 2012 a; 2012 b; 2012 c; 2013 a; 2013 b; 2013 c; Chang 2013 a; 2013 b; 2013 c). The extended rationale for providing added values for finance is as follows: Clouds provide a common platform on which to run different modelling and simulations based on Gaussian and non-Gaussian models. The Clouds then offer distributed high-performing resources for experts in different areas within and outside financial services to study and review the modelling together, including models using Monte Carlo Methods and Black Scholes Model. The Clouds allow regulations to be taken with ease while establishing and strengthening security and policy within the Clouds resources.

There are different types of clouds in the market such as Health clouds, Energy clouds, Security clouds and Telecommunications clouds, with exceptions for Finance clouds. It is apparent from the relative lack of existing literature on the subject that there has been little academic research into Financial Clouds (FC). Based on literatures and interviews (Chang et al 2010 a; 2010 c; 2011 a), we have identified several reasons for this. Firstly, a majority of financial practices are closed-source, since this relates to the way they make profits and business opportunities, and sharing this type of information will be undesirable within a business context (Bryan T, 2009). Secondly, human decision makers can overrule any computing analysis for risks and even introduce excessive risk taking that can result in adverse effects as illustrated between 2008 and 2009 (Flouris and Ylimaz, 2010). Thirdly, despite advanced technologies being introduced, many financial practices still use desktop-oriented tools such as Excel and VBA together with desktop based statistical software such as SAS. A few use Grid technologies, and of among them, not all will use Clouds (Chen, Chee, Huang, Jin, Tseng, Wang and Wong, 2010, by interviews). Fourthly, finance projects are mostly investigated by business schools which have few active involvements with Grid and Cloud communities (with one notable exception in Austria, and the new interdisciplinary centres in Oxford, UCL, KCL and Warwick, although it is the industrial vendors who are leading in this area).

2. LITERATURE REVIEW

There are three sub-sections in Literature Review, and each is presented as follows.

2.1 Organisational challenges of Cloud adoption

There are existing Cloud Computing problems experienced in the current organisational adoption of Cloud (Chang et al, 2010 a; 2011 a; 2013 b; Chang 2013). Firstly, all cloud business models and frameworks proposed by other leading researchers are either qualitative (Briscoe and Marinos, 2009; Chou, 2009; Weinhardt et al., 2009; Schubert, Jeffery and Neidecker-Lutz, 2010) or quantitative (Brandic et al., 2009; Buyya et al., 2009; Armbrust et al., 2009). Each framework is self-contained, and not related to others' work. There are few frameworks or models which demonstrate linking both quantitative and qualitative aspects but when they do, the work is still at an early stage.

Secondly, there is no accurate method for analysing risk and return other than the stock market. A limitation with current practices in the stock market is that it is subject to accuracy and reliability issues (Chang et al., 2011 b; 2011 c; 2011 c). There are researchers focusing on types of business model for which cloud business can be successful (Chou, 2009; Weinhardt et al., 2009) but these business model classifications need more cases to support them and more data modelling to validate them for sustainability. Ideally, a structured framework is required to review risk and return analysis and sustainability in systematic ways.

Thirdly, communications between different types of clouds from different vendors are often difficult to implement. Work-arounds require writing additional layers of APIs, an interface or a portal. This highlights interesting research questions such as portability; allowing existing applications on desktop or other computing environments to work on Cloud, or moving enterprise applications and services (not just files or VM) to the Cloud Computing environments. Enterprise portability of some applications from desktop to cloud can be challenging (Beaty et al., 2009; Armbrust et al., 2009). The scope of enterprise portability refers to moving enterprise applications and services, and not just files or VM over clouds.

2.2 Cloud services

Services provided by Cloud Computing implementations may be divided into a number of classes as follows:

- Software as a Service (SaaS). The term "Software as a Service" (SaaS) was first used by Saleforce.com in 1999 when they saw the vision of merging Web Services (WS) and Service Oriented Architecture (SOA). Referred to as Service or Application Clouds, these offer implementations of specific business functions and business processes that are provided with cloud capabilities. They provide applications and/or services using a cloud infrastructure or platform, rather than providing cloud features themselves. SaaS is a popular type of cloud service and provides added value on top of WS and SOA (Foster et al., 2008; Briscoe and Marinos, 2009; Buyya et al., 2009). This paper addresses financial SaaS on Clouds and provides solutions for enterprise portability.
- Platform as a Service (PaaS): provides computational resources via a platform upon which applications and services can be developed and hosted. PaaS typically makes use of dedicated APIs to control the behaviour of a server hosting engine that executes and replicates the execution according to user requests (e.g., access rate).
- Infrastructure as a Service (IaaS) is divided into Compute Clouds and Resource Clouds. Compute Clouds provide users access to computational resources such as CPUs, hypervisors and utilities. Resource Clouds contain managed and scalable resources as services to users – they provide enhanced virtualisation capabilities.

2.3 Financial Models

Gaussian-based mathematical models have been frequently used in financial modelling (Birge and Massart, 2001). As pointed out by the FSA, many banks' mathematical models assumed normal (Gaussian) distribution as an expected outcome, and might underestimate the risk for something going wrong. According to Hutchinson (2010), "The Gaussian model is too optimistic about market stability, because it uses an unrealistically high number for the key variable, the exponential rate of decay, known to its friends as alpha". To address this, other non-Gaussian financial models need to be investigated and demonstrated for how financial SaaS can be successfully calculated and executed on Clouds where Section 4 and 5 present more details. Based on the various studies (Feiman and Cearley, 2009; Hull 2009), one model for pricing and one model for risk analysis should be selected respectively. A number of methods for calculating prices include Monte Carlo Methods (MCM), Capital Asset Pricing Models and Binomial Model. MCM is often used in stochastic and probabilistic financial models, and provides data for investors' decision-making (Hull, 2009) and is our choice for MCM for pricing. On the other hand, methods such as Fourier series, stochastic volatility and Black Scholes Model (BSM) are more appropriate for volatility. As a main stream option, BSM is selected for risk analysis in this paper as BSM has finite difference equations to approximate derivatives.

2.3.1 Monte Carlo Methods in Theory

Monte Carlo Simulation (MCS), originated from mathematical Monte Carlo Methods, which is a computational technique used to calculate risk analysis and the probability of an event or investment to happen. MCS is based on probability distributions, so that uncertain variables can be described and simulated with controlled variables (Hull 2009; Waters 2008). Originated from Physics, Brownian Motions follow underlying random variables can influence the Black-Scholes models, where the stock price becomes

$$dS = \mu S\,dt + \sigma S\,dW_t. \qquad (1)$$

where W is Brownian—the dW term here stands in for any and all sources of uncertainty in the price history of the stock. The time intervals are divided into M units of length δt from time 0 to T in a sampling path, and the Brownian motion over the interval dt are approximated by a single normal variable of mean 0 and variance δt, and leading to

$$S(k\delta t) = S(0)\exp\left(\sum_{i=1}^{k}\left[\left(\mu - \frac{\sigma^2}{2}\right)\delta t + \sigma\varepsilon_i\sqrt{\delta t}\right]\right) \qquad (2)$$

for each k between 1 and M, and each is a draw from a standard normal distribution. If a derivative H pays the average value of S between 0 and T then a sample path ω corresponds to a set $\{\varepsilon_1, \ldots, \varepsilon_M\}$ and hence,

$$H(\omega) = \frac{1}{M+1}\sum_{k=0}^{M} S(k\delta t). \qquad (3)$$

The Monte Carlo value of this derivative is obtained by generating N lots of M normal variables, creating N sample paths and so N values of H, and then taking the average. The error has order $\epsilon = \mathcal{O}\left(N^{-1/2}\right)$ convergence in standard deviation based on the central limit theorem.

2.3.2 Monte Carlo Methods for Variance-Gamma Processes

Reibero and Webber (2002) demonstrate improved calculation techniques based on Monte Carlo Methods (MCM) on top of the Variance-Gamma (VG) Process, which has been a subject of studies by researchers (Carr et al., 2002; Reibero, Webber, 2002). They explain stratified sampling method and how to stratify VG bridge. They have benchmarked the methods with European options (a finance model). However, Reibero and Webber do not provide any details of hardware and software environments used for benchmarking, and there is no information for their coding algorithm. To demonstrate Variance-Gamma, we have opted for Asian options with 10,000 MCM simulations. They perform this experiment using a desktop environment, two private clouds and one Amazon EC2 public cloud as the proof of concept and benchmarking. Details are described in Section 4. The purpose of demonstration is not about the finance model; either European or Asian, but it is about presenting a systematic and logical proof of concepts. In another paper published by Reibero and Webber (2004), they explain that there is simulation bias in MCM for financial options including VG process.

2.3.3 Black Scholes Model (BSM)

The BSM is commonly used for financial markets and derivatives calculations. It is also an extension from Brownian motion. The BSM formula calculates call and put prices of European options (a financial model) (Hull, 2009). The value of a call option for the BSM is

$$C(S,t) = SN(d_1) - Ke^{-r(T-t)}N(d_2) \quad (3)$$

where $d_1 = \frac{\ln(\frac{S}{K}) + (r + \frac{\sigma^2}{2})(T-t)}{\sigma\sqrt{T-t}}$ and $d_2 = d_1 - \sigma\sqrt{T-t}$.

The price for the put option is

$$P(S,t) = Ke^{-r(T-t)} - S + (SN(d_1) - Ke^{-r(T-t)}N(d_2)) = Ke^{-r(T-t)} - S + C(S,t). \quad (4)$$

For both formulas (Hull, 2009),

- N(•) is the cumulative distribution function of the standard normal distribution
- T - t is the time to maturity
- S is the spot price of the underlying asset
- K is the strike price
- r is the risk free rate
- σ is the volatility in the log-returns of the underlying

3. MOTIVATION FOR THE CLOUD COMPUTING ADOPTION FRAMEWORK (CCAF)

We propose the Cloud Computing Adoption Framework (CCAF) to address the technical and business challenges of Cloud Computing, particularly the three business problems described earlier. CCAF aims to help organisations achieve good Cloud design, deployment and services. The CCAF is an enhancement to the work of Weinhardt and others (Weinhardt et al 2009) in which they fit technical solutions and Business Models into their Cloud Business Model Framework (CBMF). CCAF offers quantitative methods for measuring Risk and return analysis, and detailed descriptions and good practices for Cloud portability and migration. Compared with CCAF, CBMF does not offer quantitative techniques for measuring Risk and return analysis, nor does it provide detailed descriptions for Cloud portability and migration.

Foster et al. (2008) explain that Grids and Clouds are in common in terms of solutions and research questions that both Grids and Clouds are dealing with. Sobel et al. (2009) argue that Grid and Cloud are different; in particular in the way Web 2.0 is involved in Clouds right from the beginning and also that whilst Web 2.0 may be considered to be a subset of Clouds, this is not necessarily so for Grids. In contrast, Weinhardt et al. (2009) assert that the difference between Grids and Clouds is in their business models, where Clouds provide new business opportunities. This is supported by the observation that since 2007, there is an increasing number of organisations offering many different Cloud solutions and services.

The CCAF has the following advantages:

- Classification of business models to offer Cloud-adopting organisations right strategies and business cases.
- It offers a robust method to analyse risk and return of Cloud adoption accurately and systematically.
- It can deal with enterprise portability to ensure existing services from desktop or other computing systems can work in the Cloud, and allow Cloud communications between different clouds offered by different vendors.
- IT provides linkage and relationship between different cloud research methodologies, and between IaaS, PaaS, SaaS and Business Models.

CCAF can also accommodate a series of conceptual methodologies which it can apply and fit into Cloud Architecture and Business Models. For this paper, the objective is to focus on challenge of enterprise portability between desktops and clouds, and between different clouds.

3.1 Our work for research questions within the CCAF

A good framework should be able to accommodate multiple methods or solutions to work in different contexts and consolidate all towards the goal of the framework (Sander WH et al., 2004; Jiang T J et al., 2006). In an ideal situation, a framework would address research questions and provide methodology proving supporting the validity. Referring to Section 2.1, there are three business challenges to deal with for CCAF. Based on the descriptions in Section 2.3 and Section 3, our work for these research questions can be summed up as: (i) Classification; (ii) Organisational Sustainability, (iii) Portability and (iv) Linkage:

- Classification: This refers to the upper-most layer in the CCAF where the top-down strategic direction is provided to guide organisations into the right track of operating their cloud projects and businesses. Currently the Cloud Cube Model (CCM) has been used for classification of eight Cloud Business Models (Chang et al, 2010 a). Bottom-up approaches require methods of validation such as experiments, modelling and simulation. A summary of such outcomes can be used for classification for good practices, and is not focus in this paper.

- Organisational Sustainability: This includes modelling to review and evaluate cloud business projects, past and present and also enables forecasting for cloud businesses in the future. Sustainability modelling is suitable for all IaaS, PaaS and SaaS.

- Portability: This refers to enterprise portability, which involves migrating entire application services from desktops to clouds and between different clouds. For financial services and organisations that are not yet using clouds, portability involves a lot of investment. Thus is an organisational challenge (Chang et al., 2010 c; 2011 a). Portability deals with IaaS, PaaS and SaaS. Examples in Education, Health and Finance will be demonstrated. Financial SaaS (FSaaS) Portability is the focus for this paper. See Figure 1 on page 11.

- Linkage: There are two aspects to linkage. The first aspect is to determine when a service should be upgraded to the next level, and to identify direct relations between different services. The second aspect is to integrate different services in a central platform, allowing different services, roles and functionalities to work together in a linkage oriented framework where the outcome of one service can be input to another, without the need to translate from one domain or language to another.

Classification provides strategic directions and guidelines for business adopting the appropriate business models. Both (Organisational) Sustainability and Portability apply to different sectors and domains using Cloud Computing, and all lessons learned are summed up. Linkage allows integration of different services and roles.

3.2 The updated CCAF Architecture

Four research areas in the CCAF are discussed and presented in Section 3.1. The CCAF helps organisations to achieve good Cloud design, deployment and services, and having the architecture is useful for summing up useful components and recommendations for organisations undertaking Cloud migration and development. The updated CCAF Architecture is presented in Figure 1. Chang et al. (2011 b) present Business Integration as a Service (BIaaS) in the CCAF, which is ready for each layer of service and is able to integrate with other services, activities and projects by other departments (for large organisations), other organisations and other businesses in other domains. Chang et al. (2010 b) demonstrates the Hexagon Model to measure risk and return of Cloud adoption without the need to reveal confidential data, and is useful to review any Cloud project or organisation at any time. The Hexagon Model can be used to bridge the gap between qualitative and quantitative methods for case studies, which are used to demonstrate positive impacts that collaborators have gained from adopting the CCAF. The benefits of adopting CCAF, particularly in the area of Portability, can be applied to any domain including Finance, Healthcare and Education. In the Financial Cloud domain, Commonwealth Bank Australia and IBM US (Chang et al., 2010 c; 2011 a) has worked with the University of Southampton in improving the prototype of Financial Clouds and services. Referring to Figure 1, OSM stands for Organisational Sustainability Modelling to analyse risk and return of system adoption such as Cloud Computing, and portability of Cloud Computing to finance applications is the focus for this paper.

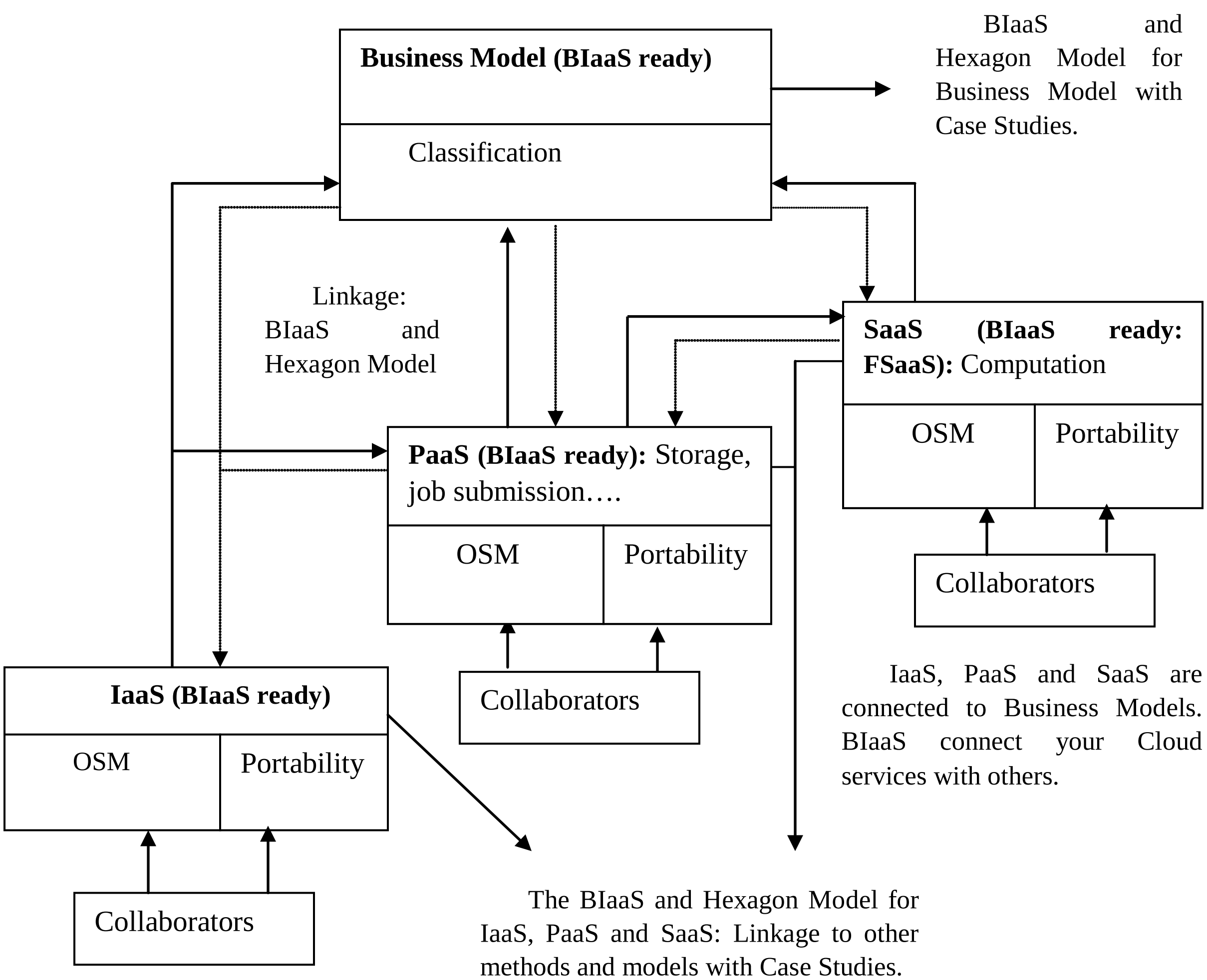

Figure 1: The updated CCAF Architecture

3.3 The CCAF: Portability for Financial Software as a Service (FSaaS)

In relation to finance, portability is highly relevant. This is because a large number of financial applications are written for a desktop environment. Although there are financial applications for Grid, not all of them are portable onto Clouds. Portability often requires rewrites in software design and the provision of an API suitable for Clouds. Apart from portability, factors such as accuracy, speed, reliability and security of financial models migrating from desktop to clouds must be considered. The second problem related to finance is there are few financial clouds, as described in opening section. Salesforce offers ondemand CRM, but it is not directly related to financial modelling. Enterprise portability from desktops to clouds, and between different clouds, is useful for businesses and financial services, as they cannot afford to spend considerable time and money fully migrating entire applications, API libraries and resources from their existing ones to clouds (Chang, et al., 2011 a). Portability must be made as easy as possible. However, there are more advantages in moving all applications and resources to clouds. These added values include the following benefits:

- The community cloud – this encourages groups of financial services to form an alliance to analyse complex problems.
- Risk reduction – the financial computing results can be compared and studied together to reduce risks. This includes running additional, less conventional models (non-Gaussians) to explore causes of errors and uncertainties. Excessive risk taking can be minimised with the aid of stricter regulations.

The Financial Software as a Service (FSaaS) is the proposal for dealing with finance-specific problems. The FSaaS is designed to improve the accuracy and quality of both pricing and risk analysis. This is essential because incorrect analysis or excessive risk taking might cause adverse impacts such as financial loss or severe damage in credibility or even another credit crunch. The research demonstration is on SaaS, which means it can calculate best prices or risks based on different values in volatility, maturity, risk free rate and so forth on cloud applications. Different models for FSaaS are presented and explained in Section 2.3 onwards. Monte Carlo Methods (MCM) and Black Scholes Models (BSM) are the core models used in the FSaaS.

4. FSaaS Portability with Monte Carlo Methods (MCM) and Black Scholes Model (BSM)

This section describes how Financial SaaS portability on clouds can be achieved. This mainly involves Monte Carlo Methods (MCM) and Black Scholes Model (BSM). Before describing how they work and how validation and experiments are done we need to describe existing practice in Finance. Visual Basic for Applications (VBA) is very commonly used in Finance applications, which include a wide range of software and tools. In contrast, HPC languages such as C++, Visual C++ and MATLAB are less commonly used. The drawback of migrating desktop applications such as VBA to Clouds mainly is because of security with the following reasons:

- VBA Macro is commonly used to support advanced techniques, but VBA Macro is a common way for writing and sending viruses (Sovereign, 2005).
- Additional security applications or tools need to be in placed to enforce security, but these tools or applications need additional work if integrations with other technologies are required.

Comparisons between VBA and HPC languages such as MATLAB are presented in Table 1.

Table 1: Comparisons between VBA and HPC languages such as MATLAB

Portability comparisons	VBA	MATLAB
Performance	It can execute fast calculations in Microsoft environments only. Better performance is available on Office 2007 and above.	It works on different platforms. It can be used in HPC environments. Applications can run on its open source equivalent.
Security	It is a concern, and needs enforced security and policy. Some vendors such as Google disable Macro, and advanced financial analysis on Cloud cannot work without it.	It has a better status than VBA although some work is in progress. MATLAB is working on its own improvement with security. It allows integrations with other security applications or tools.
Risk modelling	There is a limit for risk modelling, and it cannot go beyond 100,000 simulations in one go in our experiments.	It can go 100,000 simulations in one go provided with the right model and coding algorithms are provided.
Costs and impacts	Licence fees can be expensive. OpenOffice can be used to reduce costs, but challenge becomes interoperability with MS VBA Macro.	It is expensive if all Clouds adopt MATLAB licences, but the use of its open source equivalence (Octave) can much reduce costs.

Chang et al (2011 a) demonstrate the use of risk analysis and financial modelling on Clouds based on MATLAB and Mathematica, which offer benefits such as performance, accuracy and integration with security. This includes the selection of Linear Square Method (LSM) that can compute 100,000 simulations in one go, which takes between 4 to 25 seconds depending on the number of time steps. It can also work with IBM Fined-Grained Security Model, and it can provide a safer environment for FSaaS on Clouds.

4.1 Selection of MATLAB with emphasis on error corrections

Error corrections in financial modelling are important since when errors are identified, rectifications need to be in place and automatically corrected (Zimmermann, Neuneier and Grothmann, 2006). The rationale behind is, a slight discrepancy in financial analysis may cause adverse impacts such as financial loss. Chang et al. (2011 a) use LSM that offers better performance and accurate analysis. It is helpful if another model can be used for error corrections, and computational results from both models can be jointly used for decision-making. Chang et al. (2010 c) select Variance-Gamma Processes (VGP) for risk analysis and early version of error correction techniques. VGP is a technique used in MCM. The use of VGP offers two advantages as follows:

- It simulates the pricing and risk analysis, which include the expected and out of range data;

- It removes out of range of data, and computes simulations again, and presents the improved simulations.

In order to demonstrate the use of VGP, the core code algorithm is presented in this Section.

4.2 Monte Carlo in MATLAB – calculating the best buy/sell prices

Mathematical models such as MCM are used in Risk Management area, where they are used to simulate the risk of exposures to various types of operational risks. Monte Carlo Simulations (MCS) in Commonwealth Bank Australia are written in Fortran and C#. Running such simulations may take several hours or over a day (Chang et al., 2010 c; 2011 a). The results may be needed by the bank for the quarterly reporting period. MCM is suitable to calculate best prices for buy and sell, and provides data for investors' decision-making (Waters, 2008). MATLAB is used due to its ease of use with relatively good speed. While the volatility is known and provided, prices for buy and sale can be calculated. Part of the code (fareastmc.m) to is used to present formulas in MCM and demonstrate coding algorithm presented in Table 2.

Table 2: Coding algorithm in Monte Carlo in MATLAB for best buy/sell prices

```
dt=T/(NSteps-1);
vsqrdt=sigma*dt^0.5;
drift=(r-(sigma^2)/2)*dt;
x=randn(NSimulations,NSteps);
Smat=zeros(NSimulations,NSteps);
Smat(:,1)=S;
for i=2:NSteps,
  Smat(:,i)=Smat(:,i-1).*exp(drift+vsqrdt*x(:,i));
end
```

The following demonstrates running the code and the calculated prices. Call prices are for buy and put prices are for sale. The program calculates the lower limit, ideal value and the upper limit for each buy and sale category.

```
> fareastmc
            [LowerLimit MCPrice UpperLimit]
Call Prices: [4.196694 4.248468 4.300242]
Put Prices: [7.610519 7.666090 7.721662]
```

4.3 Coding Algorithm for Variance-Gamma Processes

Codes are written to demonstrate the VG process in the MCM. The following shows the initial part of the code, where key figures such as maturity, volatility and risk free rate are given in Table 3.

Table 3: The first part of coding algorithm for Variance-Gamma Processes

```
S=100; %underlying price
K=101; %strike
T=0.5; %maturity
sigma=0.12136; %volatility for VG model
r=0.1; %risk free rate
VG_nu=.3; %nu for VG model
VG_theta=-0.1436; %theta of VG model
nsimulations=10000; % no. of MC simulations
k=4; %2^k: the no. of resets, Asian option
nsimulations=(floor(nsimulations^.5))^2;
tmpdim=nsimulations^0.5;
omega=(1/VG_nu)*( log(1-VG_theta*VG_nu-sigma*sigma*VG_nu/2) );
```

In MATLAB, there is a function, gamrnd, to calculate variance gamma model, presented in Table 4.

Table 4: The second part of coding algorithm for Variance-Gamma Processes

```
thmean=T;
thvar=VG_nu*T;
theta=thmean/thvar;
alpha=thmean*theta;
G(:,n+1)=gamrnd(alpha,theta,nsimulations,1);
subplot(5,1,1);
subplot(2,2,1);
hist(G(:,n+1),100);
title('original gamma vars');
```

The third part of the code is to calculate stratified gamma sampling presented in Table 5. This includes replicate and tile array (repmat function) and returns the inverse of the gamma cumulative distribution function (cdf) (gaminv function).

Table 5: The third part of coding algorithm showing stratified gamma sampling

```
vvec=rand(nsimulations,1);
midxvec=1:tmpdim;
midxvec=midxvec';
midxvec=repmat(midxvec,tmpdim,1);
uvec=(midxvec-1+vvec)/tmpdim;
uvec2=gaminv(uvec,alpha,theta);
subplot(2,2,2);
hist(uvec2,100);
title('stratified gamma vars');
```

The fourth part of code in Table 6 is to calculate random variable from the normal distribution.

Table 6: The fourth part of coding algorithm

```
X(:,n+1)=normrnd(VG_theta*G(:,n+1),sigma*sigma*G(:,n+1));
subplot(2,2,3);
hist(X(:,n+1),100);
title('original normal vars');
```

This fifth part of code in Table 7 is to calculate stratifying random variables from normal distribution. This includes replicate and tile array (repmat function), reshape the array (reshape function) and computes the inverse of the normal norminv cdf (norminv function).

Table 7: The fifth part of the coding algorithm

```
G(:,n+1)=uvec2;
midxvec=1:tmpdim;
midxvec=repmat(midxvec,tmpdim,1);
midxvec=reshape(midxvec,tmpdim*tmpdim,1);
vvec=rand(nsimulations,1);
uvec=(midxvec-1+vvec)/tmpdim;
X(:,n+1)=norminv(uvec,VG_theta*G(:,n+1),sigma*sigma*G(:,n+1));
subplot(2,2,4);
```

Additional formulations in Table 8 are added to calculate the best calling price based on MCM.

Table 8: The sixth part of the coding algorithm

```
Tvec=0:1/(2^k):1;
Tvec=T*Tvec;
Tmat=repmat(Tvec,nsimulations,1);
Smat=exp( log(S)+r*Tmat+omega*Tmat+X );
Avgvec=mean(Smat(:,2:2^k+1),2);
payoffvec=max(Avgvec-K,0);
mc_callprice=exp(-r*T)*mean(payoffvec)
return;
```

4.4 The outcome of executing Variance-Gamma Processes

The outcome of executing Variance-Gamma Processes is presented in Figure 2. The top half shows differences between original and stratifying gamma random variables and the lower half shows the original and stratifying random variables from normal distribution. The stratifying model eliminates infrequent variables and also concentrates on more frequently-seen results. In that way, it is more accurate than the original modelling by MCM.

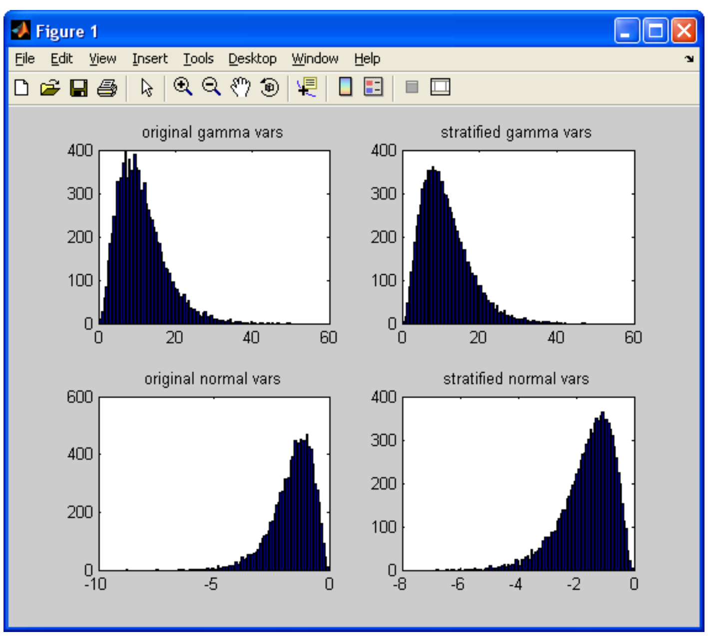

Figure 2: The Variance-Gamma Process modelling based on MCM.

The code calculates the best buying price is 0.0225. Stratified normal randomisation calculates a negative value, because theta starts as negative. The code can facilitate similar tests for different variances for volatility, maturity and risk free rate. So if either of volatility, maturity or risk free rate changes, the best values for call prices can be calculated. The outcome is a bell curve that is a normal (Gaussian) distribution. Even so, stratified sampling has corrected errors and can recalculate the best range of prices. Removal of errors is important for quality assurance of FSaaS and financial services.

4.5 Experiment and Benchmark in the Cloud environments

Codes written for Variance-Gamma Processes in Section 4.2 have been used for experimenting and benchmarking in the Clouds. 5000, 10,000 and 15,000 simulations of Monte Carlo Methods (MCM) are performed and the time taken at each of a desktop, private clouds and Amazon EC2 public clouds are recorded and averaged with three attempts. Hardware specifications for desktop, public cloud and private clouds are described as follows.

The desktop has 2.67 GHz Intel Xeon Quad Core and 4 GB of memory (800 MHz) with installed. Two Amazon EC2 public clouds are used. The first virtual server is a 64-bit Ubuntu 8.04 with large resource instance of dual core CPU, with 2.33 GHz speed and 7.5GB of memory. The second virtual server is Ubuntu 7.04 with small resource of 1 CPU with 2.33 GHz speed and 1.5 GB of memory. There are two private clouds set up. The first private cloud is hosted on a Windows virtual server, which is created by a VMware Server on top of a rack server, and its network is in a network translated and secure domain. The virtual server has 2 cores of 2.67 GHz and 4GB of memory at 800 MHz. The second private cloud is a 64-bit Windows server installed on a rack, with 2.8GHz Quad Core Xeon, 16 GB of memory. All these five settings have installed Octave 3.2.4, an open source compiler equivalent to MATLAB. Octave takes more time than MATLAB in code compilation; however, selection of Octave offers zero cost comparing to high MATLAB licence fees. Only Desktop and two private clouds have MATLAB 2007 installed. The experiment began for running the MATLAB code (in Section 4.2) on desktop, private cloud and public cloud and started one at a time.

4.6 The benchmark results

Table 9 summarises the timing benchmark result while running the modelling of assets (MoA) code (in Section 4.2) in five different hardware infrastructures. It took longer time to run simulations in the public cloud with small instances, which is not recorded in Table 9. This is due to their low CPU and memory requirements resulting in longer completion time.

Table 9: Timing benchmark to run MoA code on Octave 3.2.4

Number of simulations and time taken (sec)	5,000	10,000	15,000
Desktop	11.08	11.92	12.71
Public cloud (large instance)	11.95	12.30	13.15
Private cloud (virtual server)	11.31	12.13	12.90
Private cloud (rack server)	9.63	10.51	11.48

Refer to Table 8 for timing comparisons. Private cloud (rack server) has the best hardware requirements and running codes on 64-bit system improves the time completion. Since MoA code runs directly on the desktop instead on top of virtualised environment, this explains why the time taken in running MCM simulations on the desktop is slightly shorter than on the private cloud (virtual server). Public cloud (large instance) takes slightly more time than private cloud (virtual server) and desktop, probably because of network downtime speed, where private clouds have the advantage.

Figure 3 refers to benchmark results if using MATLAB 2007, which compile faster than Octave, are only available on desktop, private cloud (virtual server) and private cloud (rack server) hosted on Windows. The same code runs faster on MATLAB 2007, but it comes with higher prices.

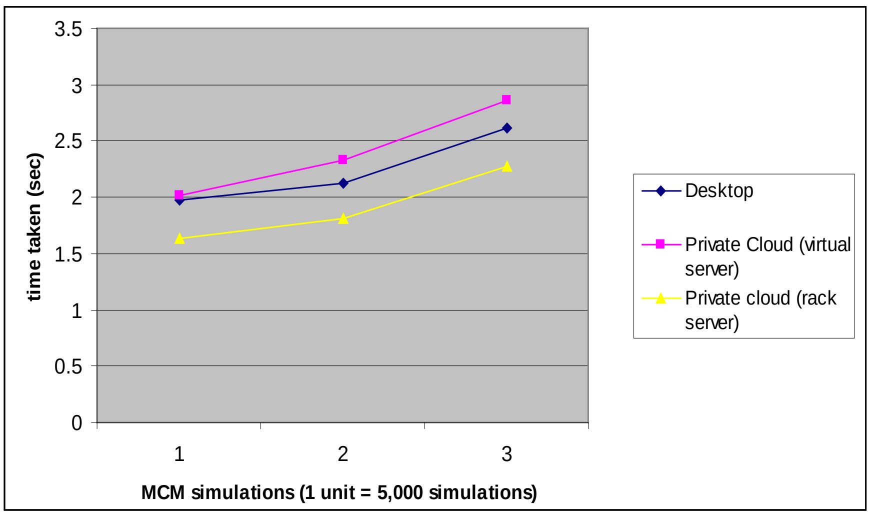

Figure 3: Timing benchmark comparison for MATLAB 2007

Desktop and two private clouds have Windows and MATLAB 2007 installed. The same experiment is repeated on these three settings, and time taken is recorded. Figure 3 shows timing benchmark, where private cloud (rack server) completes the simulations the quickest.

4.7 Black Scholes Model (BSM) Coding Algorithm

We first focus on call price and define **function [price,delta,gamma,vega,theta]=BlackScholesPrice(CallPutFlag,S,X,T,r,v).** Black Scholes use time series to calculate. This code algorithm can be divided into two parts. The first part of coding algorithm is shown in Table 10.

Table 10: The first part of Black Scholes coding algorithm

```
d1 = (log(S / X) + (b + v ^ 2 / 2) * T) / (v * T^0.5);
d2 = d1 - v * T^0.5; % T is the time to maturity
    price=0;
   if CallPutFlag == "c" ,
   price = S * normal_cdf(d1) - X * exp(-r * T) * normal_cdf(d2); % normal_cdf is a cumulative distribution to compute
if noutparams>1,
 delta=exp((b-r)*T)*normal_cdf(d1);
  theta_tmp1= -( S*exp((b-r)*T)*normal_pdf(d1)*v )/(2*T^0.5);
  theta_tmp2= -(b-r)*S*exp((b-r)*T)*normal_cdf(d1);
  theta_tmp3= -r*X*exp(-r*T)*normal_cdf(d2);
  theta=theta_tmp1+theta_tmp2+theta_tmp3;
endif
```

The second part of code algorithm is presented in Table 11.

Table 11: The second part of coding algorithm

```
else   % The following shows coding for the put price
price = X * exp(-r * T) * normal_cdf(-d2) - S * normal_cdf(-d1); % X is the strike price
if noutparams>1,
  delta=exp((b-r)*T)*(normal_cdf(d1)-1);
  theta_tmp1= -( S*exp((b-r)*T)*normal_pdf(d1)*v )/(2*T^0.5);
 theta_tmp2= (b-r)*S*exp((b-r)*T)*normal_cdf(-d1);
  theta_tmp3= r*X*exp(-r*T)*normal_cdf(-d2);
  theta=theta_tmp1+theta_tmp2+theta_tmp3;
     endif
end
if noutparams>1,
   gamma=(normal_pdf(d1)*exp((b-r)*T)) / (S*v*T^0.5);
   vega=S * exp((b-r)*T)*normal_pdf(d1)*T^0.5;
endif
```

Finite-difference methods are numerical methods for approximating the solutions to differential equations using finite difference equations to approximate derivatives (Waters, 2008; Hull, 2009). A file fdcall.m is written to calculate call price based on this method. Table 12 shows its key values for calculations.

Table 12: The key values in Finite-difference methods

```
S=100; %Spot price
K=100; %Strike
UB=115; %upper boundary
r=0.15; %risk free rate
T=.5; %maturity
sigma=0.2; %volatility
D=0.05; %dividend yield
```

The following demonstrate the key components and its values:

- strike price: the price targeted for sale.
- upper boundary: the highest possible range a price or risk can reach
- risk free rate: interest an investor would expect from an absolutely risk-free investment over a period of time.
- maturity: the loan is due to be repaid on a fixed date.
- volatility: used to quantify the risk of assets.
- dividend yield: the return on investment for an asset.
- asset steps: a specific BSM method called explicit time steps. The more steps, the more accurate the analysis.

While running this code, it calculates call option price.
> **fdcall**
option_price = 1.0675

4.8 Asset Steps Benchmark on the clouds

Our code allows editing explicit scheme time steps, where 1,500 is the maximum. 500, 1,000 and 1,500 steps are taken and the same test described in Section 4.2 is performed for Black Scholes. Time taken was recorded.

This code only focuses on calculation and therefore runs faster than the MoA code in Section 4.2. Calculation is more accurate and gets call price as 1.0704 while asset steps increase up to its maximum of 1,500 steps. Public cloud (small instance) takes the longest time to complete, and is not included for comparison. Figure 4 below shows the benchmark in other four settings.

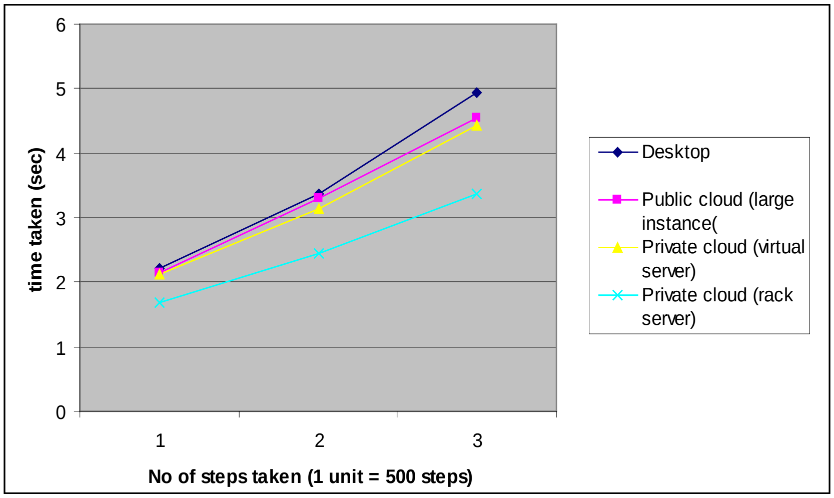

Figure 4: Timing benchmark comparison for Octave 3.2.4

5. Discussions

There are five areas for discussions, which include added values provided by portability of financial clouds and FSaaS presented as follows.

5.1 Variance in volatility, maturity and risk free rate

Calculating the impacts of violatility, maturity and risk free rate is helpful to risk management. Our code in Section 4.2 and 4.8 can calculate these three aspects with these observations. Firstly, the higher the volatility is, the lower the call price, so that risk can be minimised. Secondly, the more the maturity becomes, the higher the call price, which improves higher returns on assets before the end of life in a bond or a security. Thirdly, the higher the risk free rate, the higher the call price, as high risk free rate has reduced risk and boosts on investors' confidence level. Both Monte Carlo Methods and Black Scholes models are able to calculate these three aspects.

5.2 Accuracy

Monte Carlo Simulations are suitable to analyse pricing and provide reliable calculations up to several decimal numbers. In addition, the use of Variance-Gamma Processes reduces and corrects errors, and thus improves the quality of calculation. New and existing ways to improve error corrections are under further investigation while achieving enterprise SaaS portability onto Clouds.

5.3 Implication for Banking

There are implications for banking. Firstly, security is a main concern of the banking industry where some security issues still experience evolving challenges. This is in particular when Cloud vendors tend to mitigate this risk technically by segregating different parts of the Clouds but still need to convince clients about the locality of their data. Secondly, financial regulators are imposing tighter risk management controls. Thus, financial institutions are involved in running more analytical simulations to calculate risks to the client organisations. This may present a greater need for the use of the Cloud computation and resources. Thirdly, Cloud portability can imply letting clients to install their own libraries. Users who run MATLAB on the Cloud may only need the MATLAB application script or executable and to install the MATLAB Runtime once on the Clouds. For financial simulations written in Fortran or C++, users may also need Mathematical libraries to be installed in the Clouds.

5.4 A conceptual Financial Cloud platform

Figure 5 shows a conceptual architecture based on Operational Risk Exchange (www.orx.org), which currently includes 53 banks from 18 countries for sharing the operational risk data, and demonstrated how financial clouds could be implemented successfully for aggregating and sharing operational risk data. This cloud platform offers calculation for risk modelling, fraud detection, pricing analysis and any critical analysis with warning over risk-taking. It reports back to participating banks and bankers about their calculations, and provides useful feedback for their potential investment.

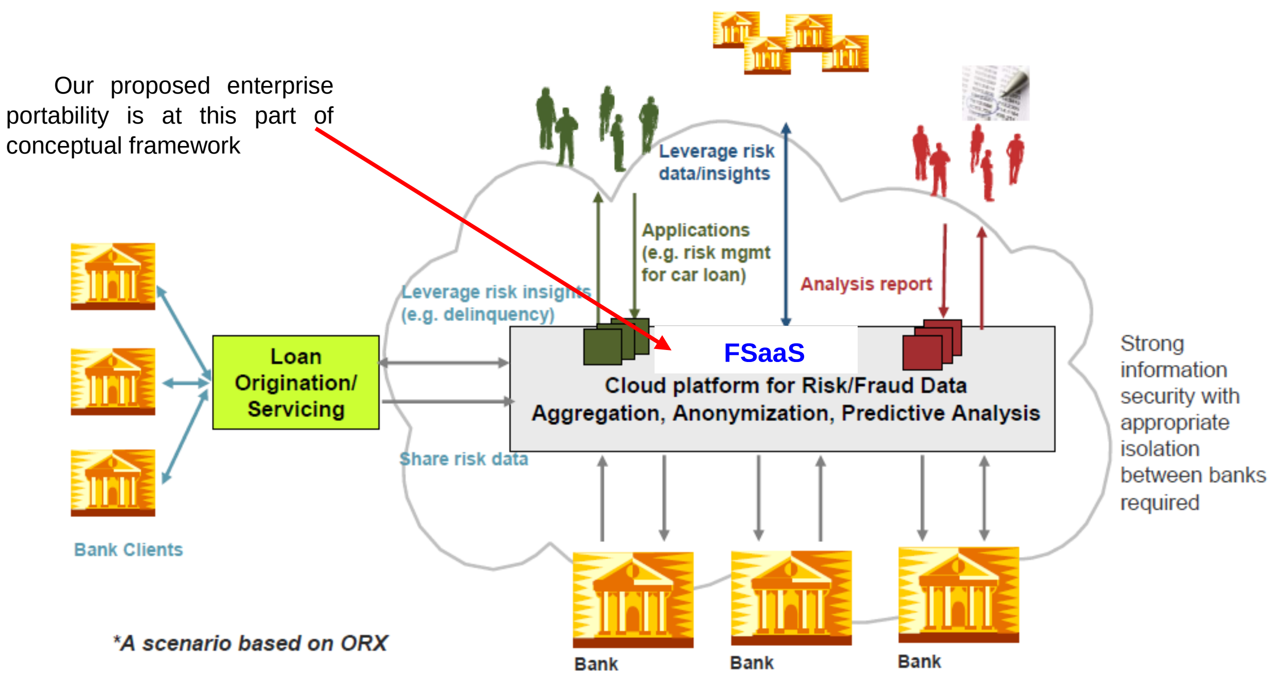

Figure 5: A conceptual financial cloud platform [using orx.org as an example] and contributions from Southampton in relations to this platform

Risk data computed by different models such as MCM, BSM and other models can be simulated and shared within the secure platform that offers anonymisation and data encryption. It also allows bank clients to double check with mortgage lending interests and calculations whether they are fit for purpose. This platform also works closely with regulations and risk control, thus risks are managed and monitored in the Financial Cloud platform. Our FSaaS is one part of the platform (the red arrow) to demonstrate accuracy, performance and enterprise portability over Clouds, and is not only in conceptual but is implemented.

5.5 Enterprise portability to the Clouds

Enterprise portability involves moving the entire application services from desktops to clouds and between different clouds, and users need not worry about complexity and use as if on their familiar systems. This paper demonstrates financial clouds that modelling and simulations can take place on the Clouds, where users can connect and compute. This has the following advantages:

- Performance and speed: Calculations can be completed in a short time.
- Accuracy: The improved models based on Variance-Gamma Processes provide a more accurate range of prices comparing to traditional computation in normal distribution.
- Usability – users need not worry about complexity. This includes using iPhone or other user-friendly resources to compute. However, this is not the focus of this journal.
-

However, the drawback for portability is that additional APIs need to be written (Chang et al., 2010 c; 2011 a). Clouds must facilitate an easy way to install and configure user required libraries, without the need to write additional APIs like several practices do. If writing APIs is required for portability, an alternative is to make APIs as easy and user-friendly as like Facebook and iPhone do. In our demonstration, there is no need to write additional APIs to execute financial clouds. In addition, virtualisation on Cloud is made easier since portability helps in virtualisation management and migration processes.

5.6 Variance-Gamma Processes (VPG) versus Least Square Methods (LSM)

Chang et al. (2011 a) demonstrates the use of Least Square Methods (LSM) used for all FSaaS and LSM provides better performance, which includes the capability to offer running 100,000 simulations in one go that take between 4 to 25 seconds depending on the complexity involved. Variance-Gamma Processes (VPG) in this paper can offer up to 20,000 simulations in one go (15,000 simulations in one go in our experiments) and it takes slightly a longer time than LSM. However, the benefits of adopting VPG are for quality assurance as it focuses more on error reduction and removal of out of range data analysis. This is important for some financial services that rely much more on stress testing and quality of their computational results. LSM offers accuracy, and the difference between two methods are, LSM reports out of range data but need not remove them. VPG in our paper involves in the removal of out of range data analysis, which is suitable for quality assurance.

5.7 Future directions

Our framework can work with finance industry to provide better accessibility, collaboration, efficiency and performance. The next target is to enforce governance for both IT and policy, as the economic downturn is also partly due to the lack of controlled governance. Our framework can provide recommendation and lesson learned for the finance industry. Additionally, Business Integration as a Service (BIaaS) is a pioneering approach to allow different services collaborating and working as a single service (Chang et al., 2011 d; 2012 b; Chang 2013 a). The use of BIaaS can compute two types of services, such as one for cost-saving and one for risk-analysis, to ensure that the financial industry can receive greater added values than current practices.

6. Conclusion and Future Work

MCM and BSM are used to demonstrate how portability, speed, accuracy and reliability can be achieved while demonstrating enterprise portability for financial applications onto Clouds. This well fits-in the third objective in the CCAF to allow portability on top of, secure, fast, accurate and reliable clouds. Financial SaaS provides a useful example to provide pricing and risk analysis while maintaining a high level of reliability and security. Our research purpose is to port and test financial applications to run on the Clouds, and ensure enterprise level of portability is workable, thus users can work on Clouds as if they work on their desktops or familiar environments. Five areas of discussions are presented to support our cases and demonstration.

Benchmark is regarded as time execution to complete calculations after portability is achieved. Timing is essential since less time with accuracy is expected in using Financial SaaS on Clouds. HPC languages such as C++ are planned to be used for the next stage. There are plans to jointly investigate Financial SaaS and its enterprise portability over clouds with Commonwealth Bank Australia and IBM US. Proof of concepts for FSaaS has been demonstrated to show the added values that CCAF and FSaaS can offer. Future collaboration includes writing and improving FSaaS based on another model, Linear Square Method, and to provide accurate and speedy pricing and risk modelling on Clouds. We hope to deliver a more improved prototypes, proof of concepts, advanced simulations and visualisation.

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